Global Trends of Lake Temperatures Observed From Space

Philipp Schneider1 and Simon J. Hook1

1Jet Propulsion Laboratory, California Institute of Technology
Pasadena, CA 91109, USA

Introduction
The temperatures of lakes and reservoirs worldwide are an excellent indicator of climate change. In situ observations of lake surface temperatures are not yet widespread on a global scale, however thermal infrared imagery can be used to infer accurate, continuous and homogenous water surface temperature of lakes and reservoirs worldwide (Schneider et al., 2009). In this study we utilize the existing archives of spacecraft thermal infrared imagery to generate multi-decadal time series of lake surface temperature for 109 of the largest inland water bodies worldwide. The data used for this purpose includes imagery from the Advanced Very High Resolution Radiometer (AVHRR), the set of (Advanced) Along-Track Scanning Radiometers ((A)ATSR), and the Moderate Resolution Imaging Spectroradiometer (MODIS). Used in combination, these data sets offer a gapless time series of daily to near-daily thermal infrared retrievals from 1981 through present. From this data we compute 25-year trends of nighttime summertime dry-season surface temperature using linear regression. The results indicate that the surface temperatures of the studied water bodies have been rapidly warming with an average rate of 0.045 °C/yr for the period 1985–2009 and rates as high as 0.13 ± 0.01 °C/yr. Worldwide, the data show far greater warming in the mid- and high latitudes than near the equator. The results provide a critical new independent data source on climate change that indicates lake warming in certain regions is greater than expected based on air temperature data.

Data and Methods

Data
• Entire global archive of ATSR-1, ATSR-2 & AATSR (1991 through 2009)
• AVHRR Pathfinder 4 km (1985 through 2009)
• MODIS Terra & Aqua (currently only used for validation)
• Only nighttime data used from all sensors to improve trend accuracy
• In situ data: 4 buoys at Lake Tahoe, 9 buoys at Great Lakes

Processing
• Extraction of 3 x 3 pixel arrays (AVHRR: 1 pixel) over each site for all images
• Cloud masking using spectral cloud tests
• Atmospheric correction & skin temperature retrieval
• Use of LOWESS smoothing for continuous estimates from irregularly obtained retrievals (Cleveland, 1979)
• Average temperature computed for July through Sept. and January through March depending on latitude
• Linear regression analysis on seasonal means

Results

Mean JAS lake surface temperatures for all lakes combined (a) and JAS trends for lakes divided in the mid-latitudes of 0° and 23.5° N. JFM trends were computed for all sites located north of 23.5° N and between 0° and 23.5° S, while JFM trends were computed for all sites located south of 23.5° S and between 0° and 23.5° S. NH: 0.052 °C/yr and SH: 0.051 °C/yr

Validation

Example of a time series of all available surface water temperature retrievals (nighttime and daytime) from 7 AVHRRs, 2 MODIS sensors and 3 ATSR sensors for Lake Tahoe, CA/US.

Conclusions

Lakes have excellent potential as indicators of a changing climate

• Availability of 30 years of thermal infrared remote sensing data permits the construction of a continuous record of lake temperatures worldwide and to complement the multivariate surface air temperature records
• Individual retrievals accurate up to 0.2 K
• Long-term trends can be determined with accuracy of ±0.013 °C/yr
• Average trend over all sites was found to be about 0.045 °C/yr (weighted global mean 0.037 °C/yr)

References